Intrinsic Channel Properties, Scattering Mechanisms, Quantum Transport Properties in Transition Metal Dichalcogenides

by

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DISSERTATION

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Advisor

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This is a dedication.

"The fact that we live at the bottom of a deep gravity well, on the surface of a gas covered planet going around a nuclear fireball 90 million miles away and think this to be normal is obviously some indication of how skewed our perspective tends to be."

— Douglas Adams, The Salmon of Doubt: Hitchhiking the Galaxy One Last Time

ABSTRACT

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Advisor: Dr. Zhixian Zhou

Major: Physics

Degree: Doctor of Philosophy

Abstract here

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Acknowledgements here

Table of Contents

List of Figures

List of Tables

List of Symbols

Symbol	Description	Unit
$\mathbf{A}$	vector potential	$\mathrm{V\,s\,m^{-1}}$
A	area	$\mathrm{cm^2}$
$A^\star$	Richardson's constant	$\mathrm{A\,s^{-1}\,K^2}$
B	magnetic field	T
C	capacitance	F
E	electric field	$\mathrm{V\,m^{-1}}$
E	energy	eV (J)
E_F	Fermi energy	eV
E_g	bandgap energy	eV
$\hat{\mathbf{H}}$	Hamiltonian	eV (joule)
I	current	A
I_ds	drain current	A
L	length	µm
L	channel length	µm
m	mass	kg
$m^\star$	effective mass	kg
n	carrier density	$\mathrm{cm^{-2}}$
n	charge carrier density	$\mathrm{C\,cm^{-2}}$
$\hat{\mathbf{p}}$	momentum operator	$\mathrm{kg\,m\,s^{-1}}$
R	resistance	$\mathrm{k\Omega\,\mu m}$ (Ω)
R_c	contact resistance	$\mathrm{k\Omega\,\mu m}$
R_H	Hall coefficient	$\mathrm{m^3\,C^{-1}}$
$\hat{\mathbf{s}}$	spin operator	$\hbar$ (J s)

T	temperature	K
V	voltage	V
V_{bg}	backgate voltage	V
V_{ds}	drain voltage	V
V_{H}	Hall voltage	V
w	channel width	µm
μ	mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_{B}	magnetic moment	$\mathrm{eV\,T^{-1}}$
μ_e	electron mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_{FE}	field-effect mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_{H}	Hall mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_p	hole mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
ρ	resistivity	$\Omega\,\mathrm{cm}$
ρ_{xx}	longitudinal resistivity	Ω
ρ_{xy}	transverse resistivity	Ω
σ	conductivity	µS
σ_{xx}	longitudinal conductivity	µS
σ_{xy}	transverse conductivity	µS
τ	scattering time	s
τ_{q}	quantum scattering time	s
Φ_{B}	barrier height	eV
$\Phi_{\mathrm{B}n}$	electron barrier height	eV
$\Phi_{\mathrm{B}p}$	hole barrier height	eV
Φ_M	metal work function	eV
Φ_S	semiconductor work function	eV
χ	electron affinity	eV
χ_S	semiconductor electron affinity	eV
ω_c	cyclotron frequency	Hz

List of Physical Constants

Symbol	**Quantity**	**Value**
μ_B	Bohr magneton	$9.274\,009 \times 10^{-24}\,\mathrm{J\,T^{-1}}$
		$5.788\,381 \times 10^{-5}\,\mathrm{eV\,T^{-1}}$
		$e\hbar/2m_e$ (atomic units)
k_B	Boltzmann's constant	$1.380\,66 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
ϵ_0	Dielectric constant	$8.854\,18 \times 10^{-12}\,\mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}$
		$8.617\,34 \times 10^{-5}\,\mathrm{eV\,K^{-1}}$
e	Elementary charge	$1.602\,18 \times 10^{-19}\,\mathrm{C}$
m_e	Electron mass	$9.109\,383 \times 10^{-31}\,\mathrm{kg}$
eV	Electron volt	$1.602\,18 \times 10^{-19}\,\mathrm{J}$
c	Speed of light	$2.997\,92 \times 10^{8}\,\mathrm{m\,s^{-1}}$
h	Planck's constant	$6.626\,07 \times 10^{-34}\,\mathrm{J\,s}$
μ_0	Permeability in vacuum	$1.256\,63 \times 10^{-6}\,\mathrm{m\,kg\,s^{-2}\,A^{-2}}$
		$4\pi \times 10^{-7}\,\mathrm{m\,kg\,s^{-2}A^{-2}}$
$\hbar$	Reduced Planck's constant	$1.054\,57 \times 10^{-34}\,\mathrm{J\,s}$ $(h/2\pi)$
$k_\mathrm{B}T$	Thermal energy	$0.025\,86\,\mathrm{eV}$ $(T = 27^{\circ}\mathrm{C})$
		$0.025\,26\,\mathrm{eV}$ $(T = 20^{\circ}\mathrm{C})$
$R_{\mathrm{K}-90}$	von Klitzing constant	$25\,812.807\,455\,55\,\Omega$

Source: CODATA Recommened Values of the Fundamental Physics Constants: 2014, Mohr *et al.*[1]

Conversion Factors

Conversion Factors	
$1\,\text{Å}$	$= 0.1\,\text{nm}$
	$= 10^{-4}\,\mu\text{m}$
	$= 10^{-8}\,\text{cm}$
	$= 10^{-10}\,\text{m}$
$1\,\mu\text{m}$	$= 10 \times 10^{4}\,\text{Å}$
	$= 10^{3}\,\text{nm}$
	$= 10^{-4}\,\text{cm}$
	$= 10^{-6}\,\text{m}$
$1\,\text{eV}$	$= 1.60218 \times 10^{-19}\,\text{J}$

Powers of Ten		
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	K
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Acronyms

SB Schottky barrier

Chapter 1

Chapter Title

1.1 Section Title

Contents here with Schottky barrier (SB). i

Chapter 2

Chapter Title

2.1 Section Title

Chapter 3

Chapter Title

3.1 Section Title

Chapter 4

Chapter Title

4.1 Section Title

References

[1] PJ Mohr, DB Newell, and BN Taylor. Codata recommended values of the fundamental constants 2014,(2015). *arXiv preprint arXiv:1507.07956*, 2015.